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**APPLICATION
FOR
UNITED STATES
LETTERS PATENT**

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**FOR: DOWNLINK POWER CONTROL METHOD
AND CDMA COMMUNICATION SYSTEM
INCORPORATING THE CONTROL METHOD**

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1 TITLE OF THE INVENTION

2 **Downlink Power Control Method and CDMA Communication System**
3 **Incorporating the Control Method**

4 BACKGROUND OF THE INVENTION

5 Field of the Invention

6 The present invention relates generally to CDMA (code division
7 multiple access) communication systems, and more specifically to a
8 downlink power control method and a system using the same.

9 Description of the Related Art

10 A transmit power control scheme for downlink (base-to-mobile)
11 channels of CDMA communication systems is described in "3GPP RAN
12 (3rd Generation Partnership Project Radio Access Network) 25.214
13 v1.3.1". According to this document, each mobile station constantly
14 monitors its downlink channel and determines its signal-to-interference
15 ratio (SIR). The mobile station compares the SIR value with a prescribed
16 target value and transmits a TPC (transmit power control) command
17 signal through an uplink channel, requesting the base station to increase
18 or decrease the power level of the downlink channel. The power level of a
19 downlink channel is varied by a predetermined incremental unit for each
20 TPC command signal. Power control will be repeatedly performed if the
21 base station repeatedly receives TPC command signals until the upper or
22 lower limit of a power control range is reached. The minimum power
23 control limit is determined in consideration of the fact that, when a power
24 decrease takes place in a downlink channel of excellent signal quality, the
25 signal quality at the reduced level still allows the base station to respond

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1 to a possible degradation which may subsequently occur due to a sudden
2 movement of the mobile station. The maximum power control limit of
3 the base station is determined by taking account of interference between
4 mobile stations which would be caused by possible racing conditions in
5 which they compete for power increase. The number of channels
6 allocated to the base station is also a determining factor of the maximum
7 limit of the control range.

8 However, one shortcoming of the prior art scheme is that, since
9 power control is effected in a specified range that prevents the base
10 station to transmit its power at a level below the minimum power control
11 limit, those mobile stations that are located near the base station would
12 receive power more than what they actually need for their downlink
13 channels. As a result, useful energy resource of a base station is wasted.
14 Another shortcoming of the prior art is that, due to the presence of the
15 upper limit, those mobile stations that are located far off the base station
16 would receive power less than what they actually need for their downlink
17 channels even when the transmit power level of the base station still has a
18 sufficient amount of allowance with respect to its maximum power
19 control limit.

20 SUMMARY OF THE INVENTION

21 It is therefore an object of the present invention to provide a
22 transmit power control technique for a CDMA base station to achieve full
23 and efficient utilization of its power resource.

24 According to a first aspect, the present invention provides a
25 method of controlling the transmit power of a plurality of CDMA

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1 downlink channels from a base station within a control range between a
2 nominal lower limit and a nominal upper limit, comprising the steps of
3 receiving, at the base station, a command signal from a mobile station
4 requesting the base station to decrease the transmit power of a downlink
5 channel, and decreasing, at the base station, the transmit power of the
6 downlink channel if the downlink channel has a quality higher than a
7 specified threshold value at the mobile station.

8 According to a second aspect, the present invention provides a
9 method of controlling the transmit power of a plurality of CDMA
10 downlink channels from a base station within a control range between a
11 nominal lower limit and a nominal upper limit, comprising the steps of
12 receiving, at the base station, a command signal from the mobile station
13 requesting the base station to increase the transmit power of the
14 downlink channel, and increasing the transmit power if total transmit
15 power of the downlink channels is lower than a specified threshold value.

16 According to a third, specific aspect, the present invention
17 provides a method of controlling the transmit power of a plurality of
18 CDMA downlink channels from a base station within a control range
19 between a nominal lower limit and a nominal upper limit, comprising the
20 steps of (a) receiving, at the base station, a command signal from a mobile
21 station requesting the base station to decrease the transmit power of a
22 downlink channel, (b) decreasing the transmit power of the downlink
23 channel if a hypothetically decremented value of the transmit power is
24 higher than the nominal lower limit, (c) decreasing the transmit power of
25 the downlink channel if the quality of the downlink channel at the mobile
26 station is lower than a specified threshold value even when the

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1 hypothetically decremented value is lower than the nominal lower limit;
2 and (d) setting the transmit power of the downlink channel equal to the
3 nominal lower limit if the hypothetically decremented value is lower than
4 the nominal lower limit and the quality of the downlink channel at the
5 mobile station is lower than the specified threshold value, receiving, at
6 the base station, a command signal from the mobile station requesting the
7 base station to increase the transmit power of the downlink channel,
8 increasing the transmit power of the downlink channel if a hypothetically
9 incremented value of the transmit power is lower than the nominal upper
10 limit, increasing the transmit power if total transmit power of the
11 downlink channels is lower than a specified threshold value even when
12 the hypothetically incremented value is greater than the nominal upper
13 limit, and setting the transmit power equal to the nominal upper limit if
14 the hypothetically incremented value is greater than the nominal upper
15 limit and the total transmit power is equal to or higher than the specified
16 threshold value.

17 According to a further specific aspect, the present invention
18 provides a method of controlling the transmit power of a plurality of
19 CDMA downlink channels from a base station within a control range
20 between a nominal lower limit and a nominal upper limit, comprising the
21 steps of receiving, at the base station, a command signal from a mobile
22 station requesting the base station to decrease the transmit power of a
23 downlink channel, decreasing the transmit power of the downlink
24 channel if a hypothetically decremented value of the transmit power is
25 higher than the nominal lower limit, incrementing a count value as long
26 as the hypothetically decremented value is lower than the nominal lower

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- 1 limit, setting the transmit power of the downlink channel to the nominal
- 2 lower limit if the count value is smaller than a predetermined count
- 3 value, and decreasing the transmit power of the downlink channel if the
- 4 count value reaches the predetermined count value.

5 BRIEF DESCRIPTION OF THE DRAWINGS

6 The present invention will be described in further detail with
7 reference to the accompanying drawings, in which:

8 Fig. 1 is a block diagram of a CDMA cell-site base station of the
9 present invention;

10 Fig. 2 is a flowchart of the operation of the transmit power
11 controller of Fig. 1 according to one embodiment of the present invention;

12 Fig. 3 is a flowchart of an interrupt routine; and

13 Fig. 4 is a flowchart of the operation of the transmit power
14 controller according to a modified embodiment of the present invention.

15 DETAILED DESCRIPTION

16 Referring now to Fig. 1, there is shown a CDMA (code division
17 multiple access) cell-site base station of the present invention. The base
18 station is comprised of a plurality of CDMA modems 14-1 through 14-N
19 provided in number corresponding to the number of wireless channels
20 allocated to the base station. The base station includes an antenna 10, a
21 duplexer 11, an uplink RF amplifier 12 and a downlink RF amplifier 13,
22 which form a common antenna system shared by all modems 14. The
23 cell-site station is connected to a base station controller of the mobile
24 network (not shown) via a line interface 20 that interfaces between the
25 modems 14 and a system controller 21. A total power detector 22 is

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1 provided to detect the total power of downlink transmissions from the
2 base station by summing the transmit power levels of all modems.

3 Each CDMA modem 14 includes a down-converter 15, an uplink
4 signal processor 16, a downlink signal processor 17, a transmit power
5 controller 18 and an up-converter 19.

6 The base station operates with the antenna 10 to establish CDMA
7 channels. Uplink spread spectrum signals from mobile stations contain
8 control information such as SIR (signal to interference ratio) and TPC
9 (transmit power control) codes produced by the mobile stations. The
10 mobile-transmitted signals, detected by antenna 10, pass through the
11 duplexer 11 to the RF amplifier 12. After the RF amplification, the signals
12 are supplied to the down-converter 15 where the radio frequency signals
13 are converted to IF (intermediate frequency) signals or baseband signals.
14 The output of down-converter 15 is fed to the uplink signal processor 16,
15 which includes a circuit for despreading the signal from a mobile station
16 that uses the same pseudonoise code as that of the modem in the uplink
17 direction and for detecting the transmitted SIR and TPC codes contained
18 in the transmitted signal as well as a control signal necessary for call
19 processing. The SIR and TPC codes detected by the signal processor 16 are
20 supplied to the transmit power controller 18 and the call processing
21 signal is applied to the system controller 21. The uplink traffic signal of
22 the mobile station is supplied from the signal processor 16 to the line
23 interface 20 and transmitted to the network.

24 Downlink signals from the network are respectively coupled to the
25 modems 14 by the line interface 20. Downlink signal processor 17

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1 processes the downlink signal by spreading it with a pseudonoise code
2 determined by the system controller 21 to produce a downlink spread
3 spectrum signal. The power level of the downlink spread spectrum signal
4 is controlled by the transmit power controller 18. The power-control
5 signal is converted to a downlink radio frequency in an up-converter 19,
6 power-amplified by the RF amplifier 13 and transmitted from the
7 antenna 10.

8 As will be described in detail, the transmit power controller 18
9 determines the transmit power of the modem based on the SIR (signal to
10 interference ratio) and TPC (transmit power control) values from the
11 uplink signal processor 16 and the current total power level of the base
12 station supplied from the total power detector 22.

13 In a first embodiment of the present invention, the transmit power
14 controller 18 operates according to the flowchart of Fig. 2.

15 When SIR and TPC codes of a given mobile station are detected and
16 supplied from the uplink signal processor 16, the operation of the
17 controller 18 begins with decision step 31 to check to see if TPC is a "0" or
18 a "1".

19 If $TPC = 0$, it is determined that the downlink channel of the given
20 mobile station is of excellent quality, requesting that the power level of
21 that channel be decremented, and flow proceeds to decision step 32. In
22 this step, the transmit power controller 18 calculates the difference in
23 decibel (dB) between the current base-station power level P_{TX} and a
24 stepsize power value P_{STP} and determines whether the difference is equal
25 to or greater than the minimum power level P_{MIN} of the controllable

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1 range of the base station. If the decision at step 32 is affirmative, flow
2 proceeds to step 33 to decrement the power level P_{TX} by the stepsize
3 value P_{STP} and returns to the starting point of the routine. If the decision
4 at step 32 is negative, flow proceeds to step 34 to compare the SIR value
5 with a predetermined threshold value T_{SIR} .

6 If $SIR \geq T_{SIR}$, it is determined that despite the fact that the
7 downlink channel of the given mobile station is of excellent quality the
8 transmit power of the base station cannot be lowered below the minimum
9 level P_{MIN} . In other words, the downlink channel still has an excellent
10 quality to tolerate a reduction of power. If this is the case, flow proceeds
11 from step 34 to step 33 to decrement the current transmit power level P_{TX}
12 by the stepsize value P_{STP} .

13 If $SIR < T_{SIR}$, it is determined that a power reduction of the
14 downlink channel would cause a quality degradation. In this case, flow
15 proceeds to step 35 to set the current power level P_{TX} equal to the
16 minimum level P_{MIN} , and returns to the starting point of the routine.

17 If $TPC = 1$ (step 31), it is determined that the downlink channel of
18 the given mobile station is of poor quality, requesting that the power level
19 of that channel be incremented. In this case, flow proceeds to decision
20 step 36, where the transmit power controller 18 calculates a sum (dB) of
21 the current base-station power level P_{TX} and the stepsize value P_{STP} and
22 determines whether the calculated sum is equal to or smaller than the
23 maximum power level P_{MAX} of the controllable power range of the base
24 station.

25 If the decision at step 36 is affirmative, flow proceeds to step 37 to

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1 determine if the current transmit power level P_{TX} is lower than the
2 minimum power level P_{MIN} . Such a lower-than-minimum situation can
3 occur if the controller 18 has previously executed step 33 following an
4 affirmative decision at step 34. If this is the case, the controller 18
5 proceeds from step 37 to step 38 to calculate a sum of minimum power
6 level P_{MIN} and the stepsize value P_{STP} and set the current power level
7 P_{TX} equal to the sum $P_{MIN} + P_{STP}$, and returns to the starting point of the
8 routine.

9 If the decision at step 37 reveals that a higher-than-minimum
10 situation exists, flow proceeds to step 39 to increment the power level P_{TX}
11 by the stepsize value P_{STP} and then returns to the starting point of the
12 routine.

13 If the decision at step 36 is negative, the controller 18 compare the
14 output signal from the total power detector 22 with a threshold value
15 T_{TOTAL} (step 40). If the current total power P_{TOTAL} is equal to or lower
16 than the threshold value T_{TOTAL} , it is determined that the base station
17 has a sufficient amount of margin to increase the power level of the
18 downlink channel without causing interference with other mobile
19 stations. If this is the case, the controller 18 proceeds to step 39 to
20 increment the current power level P_{TX} by the stepsize value P_{STP} .

21 If the decision at step 40 is negative, flow proceeds to step 41 to set
22 the current power level equal to the maximum power level P_{MAX} and
23 returns to the starting point of the routine.

24 While mention has been made of an embodiment in which the
25 incremental stepsize is of constant value, the present invention could

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1 equally be as well applied to an embodiment in which the stepsize is
2 adaptively controlled in an interrupt routine as shown in Fig. 3.

3 In Fig. 3, the interrupt routine begins with initialization step 51 in
4 which the controller 18 sets a count value C to 0, and determines, at step
5 52, if the TPC value of a downlink channel is "1", requesting the base
6 station to increase its power level. If so, the controller 18 proceeds to step
7 53 to check to see if the current power level P_{TX} of the downlink channel
8 is lower than a threshold level P_A . If P_{TX} is smaller than P_A , the controller
9 18 proceeds to step 54 to increment the count value C by one and
10 compares the count value C to a threshold value C_H at step 55. If the
11 count value C is smaller than the threshold value C_H , steps 52 to 54 are
12 repeated until the count value C exceeds the threshold value C_H . If such
13 a lower-than-threshold ($P_{TX} < P_A$) condition continues for an interval
14 corresponding to the threshold value C_H , the controller 18 proceeds from
15 step 55 to step 56 to increment the stepsize value P_{STP} by P_B , where $P_{TX} <$
16 $P_B \leq P_A$. Following step 56, the transmit power controller 18 returns to
17 the main routine. If the decision at steps 52 and 53 is negative, the
18 controller 18 returns the main routine without altering the stepsize P_{STP} .

19 A modified control algorithm of the transmit power controller 18 is
20 shown in Fig. 4 in which parts corresponding in significance to those of
21 Fig. 2 are marked with the same numerals as those used in Fig. 2.
22 According to this modification, the SIR signal is not used. Instead, a count
23 value K is employed to represent the length of time in which the
24 decremented power level is lower than the lower limit P_{MIN} of the power
25 control range.

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1 In Fig. 4, if $TPC = 0$ at step 31, the downlink channel of a given
2 mobile station is requesting the base station to decrease its power level.
3 Transmit power controller 18 thus proceeds to step 32 to determine
4 whether the difference between P_{TX} and P_{STP} is equal to or greater than
5 the minimum power level P_{MIN} of the base-station power control range.
6 If the decision at step 32 is affirmative, flow proceeds to step 61 to set a
7 count value K to 0 and decrements the power level P_{TX} by the stepsize
8 value P_{STP} (step 33) and returns to the starting point of the routine.

9 If the decision at step 32 is negative, the count value K is
10 incremented by one (step 62) and compared to a threshold value T_K (step
11 63). Thus, the count value K represents the length of time that a situation
12 $P_{TX} - P_{STP} < P_{MIN}$ continues. If $K = T_K$, the count value K is reset to 0
13 (step 61) and step 33 is executed by decreasing the P_{TX} value by the
14 stepsize P_{STP} . If $K < T_K$, flow proceeds from step 63 to step 35 to set the
15 current value P_{TX} to P_{MIN} . As a result, the power level P_{TX} will be
16 maintained at P_{MIN} as long as the situation $P_{TX} - P_{STP} < P_{MIN}$ continues
17 for an interval of time that corresponds to the threshold T_K .

18 Therefore, when the decision at step 63 is affirmative, it is
19 determined that despite the fact that the transmit power of a given
20 downlink channel has been held at minimum P_{MIN} for an extended
21 period of time, the quality of that given channel is still excellent to
22 tolerate a further reduction of power. For this reason, the controller 18
23 proceeds to step 33 to further reduce the current transmit power level
24 after resetting the K value to zero at step 61.

25 If $TPC = 1$ at step 31, indicating that the mobile station is

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- 1 requesting a power increase, the controller 18 proceeds to step 64 to reset
- 2 the count value K to zero before proceeding to decision step 36.